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N77-33742



TORNADO DETECTION DATA REDUCTION AND ANALYSIS

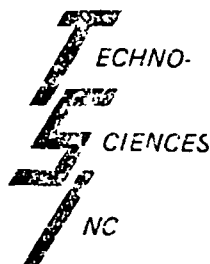
FINAL REPORT

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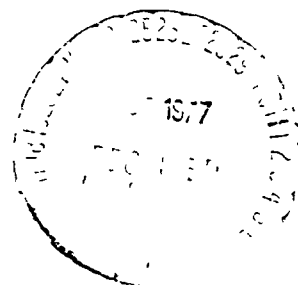


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16 Abstract This report reviews work performed under NASA Contract NAS5-23508. The work consisted of the development of various data reduction and analysis computer programs with applications to measured data. A computer simulation was also developed.					
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PREFACE

The purpose of this contract was to provide data processing and analysis in support of two GSFC programs: tornado detection by analysis of radio frequency interference in various frequency bands and sea state determination from short pulse radar measurements. Extensive data reduction efforts were performed in support of these programs. A new and unique backscatter simulation was implemented to predict radar performance as a function of the wind velocity. Computer programs were developed for the various data processing and analysis goals of the contract effort and delivered to GSFC.

I. Introduction

The data supplied to Techno-Sciences for reduction and analysis consist of 9 track, 800 bpi digital tapes in various record formats and include, in addition to the data records, records indicating the wind state at the measuring platform, aircraft orientation, altitude, and time of recording. These data were collected over several experiments and have several corresponding formats. Therefore it was necessary for Techno-Sciences to develop highly flexible programs to be able to handle the various formats. Over 60 tapes have been involved in the analysis and data reduction job. These tapes were generated under a variety of sea conditions providing an effective data base for investigation.

An important tool in the difficult task of determining sea state conditions from short pulse radar data is the use of simulated data. Data generated by simulations is highly controlled so that it is possible to find and evaluate estimation methods without uncertainty as to the true value of the quantity to be estimated. Techno-Sciences developed a 2 dimensional computer simulation during the contract period. The modelled data has a high degree of correlation with the measured data in appearance.

II. Short Pulse Radar Simulation

The problem of sea state estimation from measured short pulse radar information is very complex. Particularly complicating the problem is the lack of accurate "ground truth" data, i.e. the lack of exact knowledge of what an accurate estimate on any particular segment of data is. A good way of removing this problem is to develop computer simulations where the estimated parameters can be accurately known and controlled.

As a part of the contract effort, Techno-Sciences has developed a two-dimensional simulation of the received pulse under a Gaussian surface model. A listing of the program appears in Appendix A along with a sample printout of several pulses. The surface is allowed to consist of any combination of a deterministic sinusoidal component and a Gaussian component with a Pierce-Moskowitz spectrum under operator control. In each case, the period and amplitude is variable. The random portion is generated using an FFT on randomly generated frequency components whose variances are proportional to the Pierce-Moskowitz spectrum at each frequency. The simulation of the pulse return is based on equation (4) of Spectrum of Power Scattered by a Short Pulse From a Stochastic Surface, by David Levine, NASA report X-952-74-299, August 1974. The specular reflection points are found by interpolation between samples of the derivative of the surface where it goes through zero.

It has been found that the simulated results agree well with the measured data.

Appendix A
SHORT PULSE RADAR SIMULATION
Program Listing and Sample Printouts

Program SIMUL - Program Listing

PAGE 0001

4

```

$ASSM
SIMUL PROG 2 D SHFT PULSE SCATTER SIMULATION LDD
$FLST
$FORT
C PROGRAM TO SIMULATE A MODIFICATION OF EQN (4) IN THE TIME
C DOMAIN OF "SPECTRUM OF POWER--" BY LEVINE OF AUG 1974
C THE STATIONARY POINTS ARE FOUND FOR A GIVEN SURFACE
C USING FFT TECHNIQUES
C BOTH A SINUSOIDAL AND A GAUSSIAN SURFACE
C COMPONENT ARE ALLOWED THE SURFACE
C IS GENERATED IN THE FREQUENCY DOMAIN
C TO GET THE DESIRED SPECTRUM THE
C RANDOM SURFACE IS FIEFE-MOSKOWITZ
C WITH GIVEN PEAK FREQUENCY AND
C RMS VALUE AS INPUT THE SINUSOIDAL
C PART HAS THE SAME PERIOD BUT ANY
C OTHER CHOSEN RMS VALUE
C PROGRAM BY TECHNOLOGICAL SCIENCES, INC
C
C IMPLICIT INTEGER*2 (I-N)
C INTEGER*4 IRAN
C COMPLEX Z(1024), ZD(1024), ZID(1024), CMPLX, CONJG
C COMPLEX W, ES
C DIMENSION TEL(13), IGFDT(21), IFLMT(21), LAST(31)
C DIMENSION FANG(1024), FFFT(1024)
C EQUIVALENCE (FANG(1), Z(1)), (CFFMT(1), ZID(1))
C TANG(1)=SIN(X*200)
C EFC(1)=FIEFE-MOSKOWITZ SPECTRUM
C EFC(X)=A2+E FC=MIN(170, E62U4/(X*X)) **2**3)
C =ANGULAR SURFACE FREQUENCY
C IFMT=RANDOM NUMBER GENERATOR
C GAUSSIAN PULSE SHAPE
C PULSE(X)=EXP(-(X/SIGFIS)**2)/2)
C (SIN(X)**2)*ANTENNA POWER GAIN PATTERN
C GAIN(X)=SIN(X/ANGHAL)/ANGHAL/ABS(CX/ANGHAL), 1 E-3)**2
C DATA SIGTIM, OUS/
C DATA IRAN, 1274-21/
C DATA NFFT, 1024
C DATA LU, 3/
C DATA P2, 2.2, .53/
C DATA C, DT, PULSTM, FO, TO, .00, .25, .01, 13900 /
C C=FEED OF LIGHT DT=TIME IN F, PULSTM=PULSE DURATION
C DATA I3, 3/
C DATA I4, 4/
C DTOR =DEGREES TO RADIANS CONVERSION
C DATA DTOR, .01745329/
C DATA IONE, IEI, 1, 100000/
C DATA IGDFTS, 1/
C MC=FO*F2
C NFFT2=NFFT 2
C NFFT21=NFFT2+1

```

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```

25      WRITE(0,25)
      FORMAT(39HENTER RMS SINUSOIDAL(M),
1RMS RANDOM F-M(M),PERIOD(M)/F8)
26      READ(0,26) FMSIN,RMSRAN,PERIOD
      FORMAT(8F2)
      WRITE(0,27)
27      FORMAT(39HENTER RC 3DB CUTOFF *PULSE DUR(F8) )
      READ(0,28) FOTS
      WRITE(0,31)
31      FORMAT(30H WAVE REPEATS,PULSE REPEATS(I5))
      READ(0,32) IRPTW,IRPTP
32      FORMAT(8I5)
      WRITE(0,41)
41      FORMAT(11HBLOCKS?(I5))
      READ(0,32) IELPS
      RH0=EXP(-P2*FOTS*DT/PULSTM)
      PH01=SQRT(1-RH0*RH0)
      EG2U4=P2*P2*1.5/(PERIOD*PERIOD)
      AZ=P2*RMSRAN*RMSRAN*EG2U4
      ALTUD=2000.
      CZ=C/2.
C CONVERT FROM PULSE TIME SIGMA TO RANGE SIGMA
      SIGPLS=SIGTIM*(C2
C RINGING=ASSUMED PULSE START,END POINT
      RINGINC=6 *SIGPLS
      ANGLIN=12
      ANGCTR=ANGLIN+DTOR
      BINWTH=25
      ANGSCD=BINWTH+DTOR/2
      ANGMAX=ANGCTR+ANGSCD
      ANGMIN=ANGCTR-ANGSCD
      ANGVAL=ANGSCD/33
      YC=ALTUD*TAN(ANGMIN)
C SET UP GRID
      GDINC=1399,FLGAT(IGDFTS-1)
      DO 5 I=1,IGDFTS
5      IGRD(I)=FLGAT(I-1)*GDINC+.5
      YCDB=ALTUD*(TAN(ANGMAX)-TAN(ANGMIN))
      DY=YCDB*FLGAT/NFFT
      LY2=DY/2
      YC2=YC-DY2
C DF*DY=1/NFFT
      DF=1/YCDB
      FPDF=SQRT(DF)
      DW=P2*DF
C DW=DELTA OMEGA,DF=DELTA FREQ
C SET UP FFT TABLE
      CALL FOURIT(5,NFFT,TEL,0)
C SET BLOCK COUNTER TO ZERO BEFORE LOOPING
      ICOUNT=0
C SET UP RANDOM PART OF WAVE TRANSFORM WITH SPECTRUM SPEC(X)
C DC PARTS=0

```

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```

40  Z(1)=CMPLX(0.,0.)
    ZD(1)=CMPLX(0.,0.)
    ZDD(1)=CMPLX(0.,0.)
    DO 1 I=2,NFFT21
      X=FLOAT(I-1)*DW
      Z(I)=CMPLX(SQRT(SPEC(X))*RANDG(1RAN),0.)*RTDF
1    CONTINUE
      IFREQ=Y3DB/PERIOD+.5
      UP=NON-RANDOM WAVE COMPONENT
      Z(IFREQ)=Z(IFREQ)+CMPLX(RMSSIN/SQRT(2),0.)
      C SET UP FOR PLOT SCALE FACTORS
      SCALE=RMSSIN**2
      X=FLOAT(IFREQ-1)*DW
      SCALE1=SCALE**X
      SCALE2=SCALE1**X
      DO 2 I=2,NFFT21
        X=FLOAT(I-1)*DW
        XX=SPEC(X)*2.*IF
        SCALE=SCALE+XX
        XX=XX**X
        SCALE1=SCALE1+X
        XX=XX**X
        SCALE2=SCALE2+X
        W=CMPLX(0.,X)
        ZD(I)=W*Z(I)
        ZDD(I)=W*ZD(I)
2    CONTINUE
      SCALE=SQRT(SCALE)
      SCALE1=SQRT(SCALE1)
      SCALE2=SQRT(SCALE2)
      DO 3 I=2,NFFT21
        IC=NFFT+2-I
        Z(IC)=CONJG(Z(I))
        ZD(IC)=CONJG(ZD(I))
        ZDD(IC)=CONJG(ZDD(I))
3    CONTINUE
      CALL FOURIT(E,NFFT,TEL,IONE)
      CALL FOURIT(ZD,NFFT,TEL,IONE)
      CALL FOURIT(ZDD,NFFT,TEL,IONE)
      C FIND STATIONARY POINTS ASSUMING LINEAR INTERPOLATION
      C AND PLOT Z,Y FIRST, ZD DEFINITI"ATI"E3
      CALL SETGE(DLU,IGFD,IGDPTS,IEIG)
      IMDIF=(Y02+DY),ALTUD - REAL(ZD(1))
      I=0
      DO 4 I=1,NFFT
        Y=FLOAT(I)*DY+Y02
        TANTHT=Y/ALTUD
        TANHIF=REAL(ZD(I))
        TANDIF=TANTHT-TANHIF
        IF (TANDIF*IMDIF.GT.0.) GO TO 6
        DLT=IMDIF/(IMDIF-TANDIF)
        DLT1=1-DLT

```

```

Y=Y+DLT*DY
HEIGHT=FEHL(Z(I-1))*DLT1+DLT*REHL(Z(I))
DERIV=REHL(ZD(I-1))*DLT1+DLT*TANALF
DERIV2=REAL(ZDD(I-1))*DLT1+DLT*REAL(ZDD(I))
K=K+1
RANGE(K)=SQRT(Y*Y+(ALTUD-HEIGHT)**2)
ANG=ATAN(DERIV)
RADCRV=((1+IEFIV*DERIV)**1.5)/DERIV2
CRDOT(K)=SQRT(HBS(RADCRV/((RADCRV-RANGE(K))*RANGE(K))))
CRDOT(K)=CRDOT(K)*GAIN(ANG-ANGCTR)
6 CONTINUE
IF(IRPTW.EQ 0)GO TO 4
IFLDT(1)=20.*REAL(Z(I))/SCALE+233.5
IFLDT(2)=20.*REAL(ZD(I))/SCALE1+700.
IFLDT(4)=20.*TANTHT/SCALE1+700.
IFLDT(3)=20.*REAL(ZDD(I))/SCALE2+1167.5
DO 30 J=1,IRPTW
C REPEAT TO SPREAD SCALE
30 CALL PLOTIT(IFLDT, LAST, I4, IONE)
4 TMDIF=TANDIF
NUM=K
C REORDER IN INCREASING RANGE
10 DO 7 K=2, NUM
IF(RANGE(K-1) GT. RANGE(K)) GO TO 8
7 CONTINUE
GO TO 9
8 X=RANGE(K)
RANGE(K)=RANGE(K-1)
RANGE(K-1)=X
A=CRDOT(K)
CFDOT(K)=CFDOT(K-1)
CFDOT(K-1)=A
GO TO 10
9 CONTINUE
3 GEN=ATE WUTFUTE NUM
TIME=(RANGE(1)-RNGINC)/C2
Y=0
I=1
IFLDT(1)=0
IFLDT(2)=0
IFLDT(4)=0
21 FCFHT(1)=0
11 TIME=TIME+DT
FG=C2*TIME
C RG=RANGE FOR PULSE CENTER
C RGMH, RGMIN=STAFF END
RGMH=RG+RNGINC
RGMIN=RG-RNGINC
C FIND REFLECTOR LIMITS, MINV, MAXV
C I E THREE IN THE RANGE BIN
DO 12 I=1, NUM
IF(RANGE(I) GE RGMIN) GO TO 13
12 CONTINUE

```

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      ICOUNT=ICOUNT+1
      IF(ICOUNT LT IELKS) GO TO 40
      STOP
13    MINV=I
      DO 14 I=MINV,NUM
      IF(RANGE(I).GT.RGMA) GO TO .5
14    CONTINUE
      I=NUM+1
15    MAXV=I-1
      ZZ=CMPLX(0.,0.)
      C GENERATE OUTPUTS
      C & PLOT THEM
      IF(MAXV LT MINV)GO TO 20
      DO 16 I=MINV,MAXV
      ANG=WO*(RANGE(I)-RANGE(MINV))/C2
      W=CMPLX(COS(ANG),SIN(ANG))
      ZZ=ZZ+CR00T(I)*PULSE(RANGE(I)-RG)*W
16    CONTINUE
      C FILTER
20    X=RH0*Y+RH01*(CABS(ZZ)**2)
      Y=X
      IF(IRPTP.EQ.0)GO TO 11
      IPL0T(1)=1400*X*ALTUD
      DO 24 I=1,IFFTF
24    CALL PLOTIT(IPL0T, LAST, IONE, IONE)
18    FORMAT(1H 4E18 6,4I7)
      GO TO 11
      END
      U      EXT FUNC
      IPAN    INT4 VAR
      UNO     CMPX VAR
      UNO     CMPX VAR
      UNO     CMPX VAR
      UNO     CMPX VAR
      UNO     EXT FUNC
      UNO     EXT FUNC
      W       CMPX VAR
      W       CMPX VAR
      ZEL     REAL VAR
      ZEL     INT2 VAR
      ZEL     INT2 VAR
      ZEL     INT2 VAR
      ZEL     REAL VAR
      ZEL     REAL VAR
      ZEL     STATE FN
      ZEL     EXT FUNC
      ZEL     EXT FUNC
      ZEL     FORM PAR
      ZEL     EXT FUNC
      ZEL     EXT FUNC
      ZEL     STATE FN
      ZEL     FORM PAR
      ZEL     REAL VAR

```

EXF	EXT FUNC
AMIN1	EXT FUNC
EGZU4	REAL VAR
R	EXT FUNC
PULSE	STATE FN
X6	FORM PAR
SIGPLS	REAL VAR
GAIN	STATE FN
X8	FORM PAR
ANGVAL	REAL VAR
AMX1	EXT FUNC
RES	EXT FUNC
SIGTIM	REAL VAR
NFFT	INT2 VAR
LU	INT2 VAR
P2	REAL VAR
C	REAL VAR
DT	REAL VAR
PULSTM	REAL VAR
FO	REAL VAR
I3	INT2 VAR
I4	INT2 VAR
DTQR	REAL VAR
IQNE	INT2 VAR
IEIG	INT2 VAR
IGIFTS	INT2 VAR
WO	REAL VAR
NFFT2	INT2 VAR
NFFT21	INT2 VAR
Z5	LABEL
CH	EXT FUNC
Z6	LABEL
AMESIN	REAL VAR
AMESPH	REAL VAR
PERIOD	REAL VAR
Z7	LABEL
FOTS	REAL VAR
J1	LABEL
J2	LABEL
IRFTW	INT2 VAR
IRFTP	INT2 VAR
41	LABEL
IELKS	INT2 VAR
FHO	REAL VAR
FHO1	REAL VAR
SORT	EXT FUNC
ALTUD	REAL VAR
CZ	REAL VAR
ANGINC	REAL VAR
ANGLIN	REAL VAR
ANGCTR	REAL VAR
BMWITH	REAL VAR

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```

ANG3DB REAL VAR
ANGMHA REAL VAR
ANGMIN REAL VAR
YO REAL VAR
GDINC REAL VAR
FLOAT EXT FUNC
FLOAT2 EXT FUNC
5 LABEL
I INT2 VAR
.Y EXT FUNC
YJDB REAL VAR
DY REAL VAR
DY2 REAL VAR
YQ2 REAL VAR
DF REAL VAR
RTDF REAL VAR
DW REAL VAR
FOUP1T EXT FUNC
ICOUNT INT2 VAR
40 LABEL
$F EXT FUNC
1 LABEL
A REAL VAR
RANDG EXT FUNC
$H EXT FUNC
IFREQ INT2 VAR
$L EXT FUNC
$A EXT FUNC
SCALE REAL VAR
SCALE1 REAL VAR
SCALE2 REAL VAR
2 LABEL
XY REAL VAR
$K EXT FUNC
3 LABEL
IC INT2 VAR
SETGFD EXT FUNC
THDIF REAL VAR
REAL EXT FUNC
K INT2 VAR
4 LABEL
Y REAL VAR
TANTHT REAL VAR
THHLF REAL VAR
THHDIF REAL VAR
6 LABEL
DLT REAL VAR
DLT1 REAL VAR
HEIGHT REAL VAR
DEEIV REAL VAR
DEEIV2 REAL VAR
ANG REAL VAR

```

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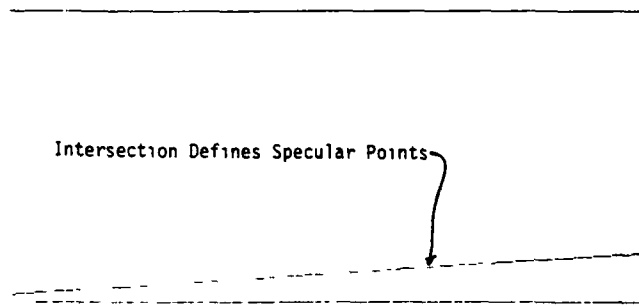
ATHN      EXT FUNC
RADCRV    REAL VAR
JA         EXT FUNC
JO         LABEL
J          INT2 VAR
PLOTIT     EXT FUNC
NUM1       INT2 VAR
10         LABEL
7          LABEL
8          LABEL
9          LABEL
TIME       REAL VAR
21         LABEL
11         LABEL
RG         REAL VAR
RGMAX      REAL VAR
RGMIN      REAL VAR
12         LABEL
13         LABEL
.S         EXT FUNC
MINV       INT2 VAR
14         LABEL
15         LABEL
MAV        INT2 VAR
20         LABEL
16         LABEL
CHES       EXT FUNC
24         LABEL
18         LABEL
.V         EXT FUNC

```

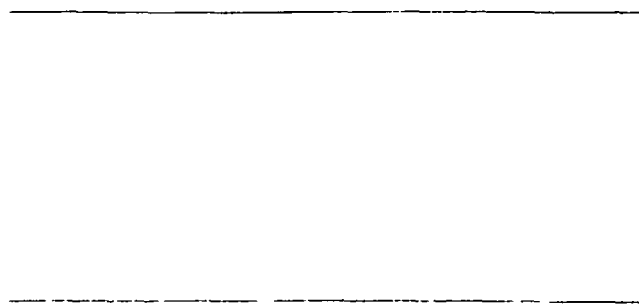
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Simulated Surface First Derivative



Simulated Surface

RANGE →



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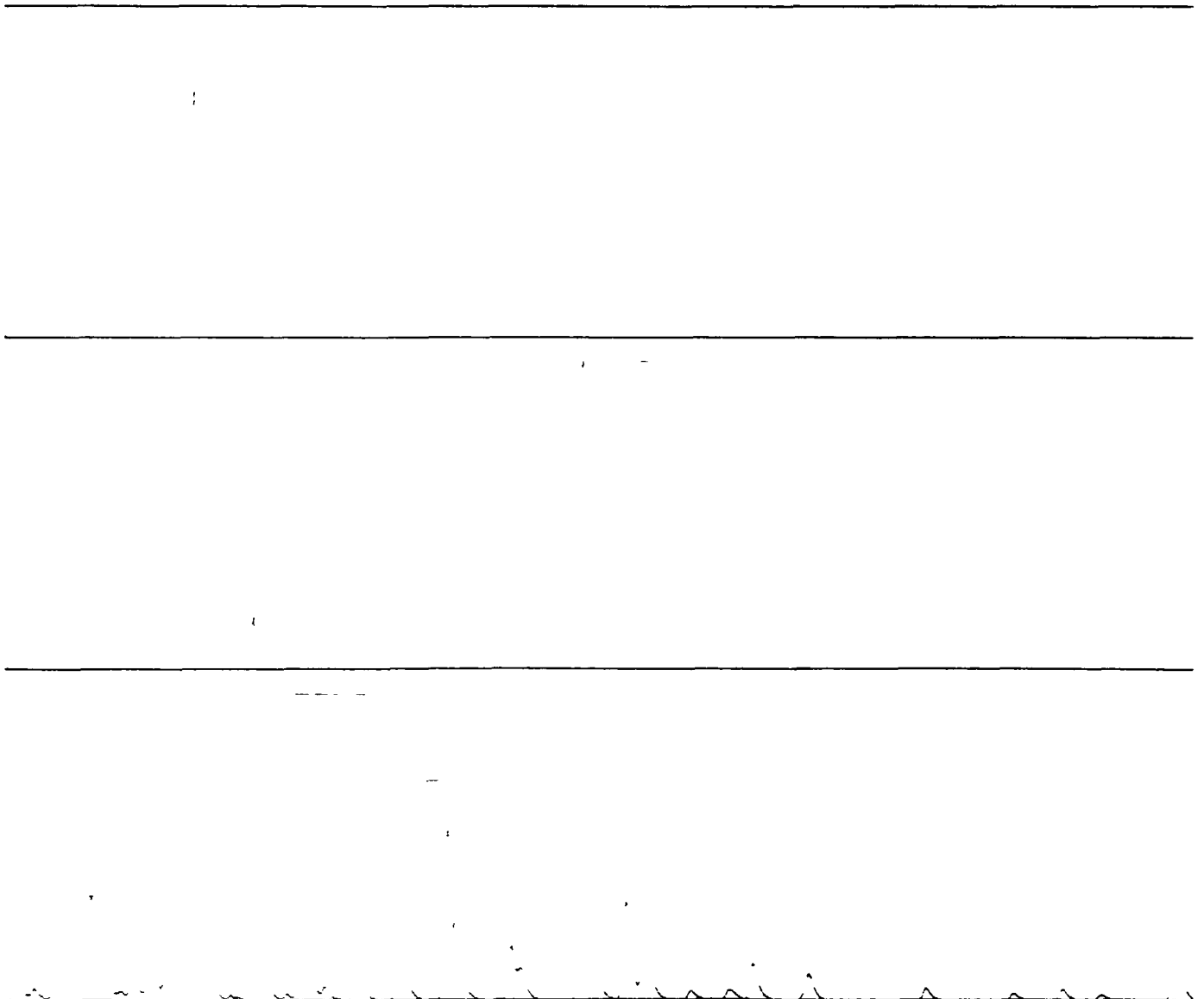
Program SIMUL - Sample Pulse

13

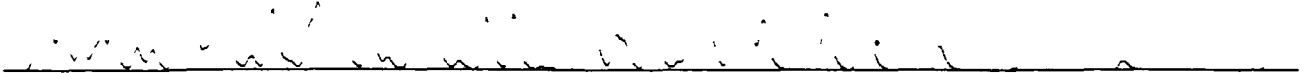
TIME →

Program SIMUL - Sample Pulse

14



Program SIMUL Sample Pulse



Appendix B
SUBROUTINES
Program Listings

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PAGE 3

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Program RANDG

PAGE 0001

20

```
*HSSM
RANDG  PROG GAUSSIAN RANDOM NUMBER GENERATOR LDD 3/76
EFLST
*FOUT
```

```
FUNCTION PANIG(IY)
C IY IS AN INITIALISING VALUE, AND L1 9 DIGITS,
C INTEGER*4.  NORMAL NUMBERS GENERATED BY SUMMING
C 12 UNIFORMS IN THE USUAL FASHION.  RANDU ROUTINE
C IS USED (NOT CALLED).
```

```
C
      X=0.
      DO 1 I=1,12
      IY=IY*65539
      IF(IY.GT.0)GO 10 2
      IY=IY+2147483647+1
2     X=X+FLOAT(IY)
1     CONTINUE
      RANDG=X/2147483647.- 5.
      RETURN
      END
```

```
RANDG  FUNC /SUE
RANDG  FUNC VAR
.O      EXT FUNC
P       EXT FUNC
IY      FORM PHP
1       FEHL VAF
1       LABEL
1       INT4 VAR
2       LABEL
FLOAT  EXT FUNC
```

0000 ERPOPS

Program RANDU

PAGE 0001

21

```

$ASSM
RANDU PROG RANDOM NUMBER GENERATOR LDD 3/76
EFLST
$FORT
      FUNCTION RANDU(IY)
C NOTE THAT IY IS INTEGER*4
C RESULT IS UNIFORM (0,1) BY IEM SSP
C IY SHOULD BE INITIALLY ODD WITH LT 9 DIGITS
      IY=IY*65539
      IF(IY)5,6,6
      IY=IY+2147483647+1
      RAND=IY
      RANDU=RAND*.4656613E-5
      RETURN
      END
RANDU  FUNC/SUB
RANDU  FUNC VAR
Q      EXT FUNC
P      EXT FUNC
IY     FORM PAF
S      LABEL
S      LABEL
RAND   REAL VAR
.W     EXT FUNC
0000 EPROPS

```

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